BULLETIN 631 JULY, 1942

A Comparison of Legume Hays for Milk Production

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A COMPARISON OF LEGUME HAYS FOR MILK PRODUCTION

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When this project was begun, in 1925, the question was frequently asked whether alfalfa hay was sufficiently more valuable than clover hay to warrant the expense of meeting the seed cost and soil requirements necessary to grow it successfully, especially in eastern Ohio. Much of the soil of Ohio required medium to heavy applications of lime, and in many places artificial drainage was necessary to grow alfalfa successfully. Clover was somewhat less exacting and fitted better into crop rotations. Alfalfa hay and seed commanded a much higher price on the market than clover. Was the difference in milk-producing value between alfalfa and clover hay sufficient to warrant the difference in prices? Is the protein in clover hay or soybean hay inferior to that in alfalfa hay for growth and milk production? What effect would the continuous feeding of either of these legumes as the sole roughage have on the development and well-being of the cow and her calf? These and other questions led to this project.

The soybean plant was grown in Ohio for hay in limited amounts when this experiment was started and could be substituted for either alfalfa or clover as hay. Soybeans could be grown on much more acid and less well-drained land and, being an annual, could be grown when a failure of alfalfa or clover was evident. Soybeans were, therefore, included in the project.

Since this project was started, the situation has changed greatly. Much larger amounts of alfalfa and soybean hays are produced in Ohio. The amount of red clover has declined, and clover seed has become about as expensive as alfalfa seed. The price of alfalfa hay has declined. Because it will grow on more acid soil, alsike clover is replacing the medium red clover.

REVIEW OF THE LITERATURE

Numerous experiments have been conducted to determine the feeding values of the various legumes, but not many have been designed to determine directly the relative values of these three legumes for dairy cows when fed over long periods of time. The results of some of the experiments bearing most directly on this project are reviewed.

Many analyses of these legumes show wide variations in composition due to stage of growth at harvest, curing conditions, and other factors.

Armsby (1, 2) of Pennsylvania reported the composition and productive values per 100 pounds of alfalfa, clover, and soybean hays as shown in table 1. These figures show the highest productive value for soybean hay and the lowest for alfalfa, evidently owing to the higher quality of the soybean hay. Soybeans were usually cut earlier when these analyses were made, in 1905, than now (1942), but the reverse was true of clover. Note the low fat content of the soybean hay, which indicates that the seeds were not developed.

[1]The author is much indebted to the various men who cared for the cattle, to other members of the Dairy Industry Department of the Ohio Agricultural Experiment Station for criticisms and suggestions, and to R. G. Washburn for collecting and analyzing blood samples.

TABLE 1.—Composition and productive values of hays
(After Armsby)

Hays	Dry matter	Crude fiber	Protein	Carbo-hydrates	Fats	Productive values
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Calories*
Alfalfa	91.6	25.00	6.93	37.33	1.38	34,413
Clover	84.7	24.80	5.41	38.15	1.81	34,748
Soybeans	88.7	22.30	7.68	38.72	1.54	38,656

TABLE 2.—Net energy values of feeding stuffs
(After Armsby)

Hay	Dry matter	Digestible crude protein	Net energy values
	Per cent	*Per cent*	*Per cent*
Alfalfa	91.4	10.6	34.23
Alfalfa in bloom	92.5	10.5	32.33
Clover	87.1	7.6	38.68
Clover in bloom	86.1	8.1	39.12
Soybean	91.4	11.7	44.03

TABLE 3.—Composition of alfalfa and clover hays
(After Brooks)

Hay	Ash	Protein	Fiber	Nitrogen-free extract	Fat
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Alfalfa	7.9	13.5	27.2	33.2	3.20
Alsike	9.7	14.0	23.1	36.1	2.10
Red clover	7.6	13.2	24.2	37.4	2.60

TABLE 4.—Net energy per kilogram of dry matter for maintenance
(After Forbes)

Hay	Net energy	Utilization of net energy
	Calories	*Per cent*
Alfalfa	1,272	69.2
Soybean	1,595	74.8

Later figures by Armsby (2) show the same relation in net energy value but do not show the protein of clover in bloom to be equal to that of alfalfa in bloom. Table 2 contains these data.

Brooks (6) of Massachusetts reported the composition of alfalfa and clovers as shown in table 3. These figures also show the protein practically equal in the three hays.

The comparison in table 4 was reported by Forbes (8) at the Pennsylvania Station.

The average figures shown in table 5 are taken from Morrison's tables (22).

TABLE 5.—Composition and energy utilization of legumes

(After Morrison)

Legume	Dry matter	Total protein	Digestible crude protein	Total digestible nutrients	Net energy values per 100 pounds	Number of analyses
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Therms*	
Alfalfa hay	90.4	14.7	10.6	50.3	41.5	242
Red clover hay	88.2	11.8	7.0	51.9	42.8	183
Soybean hay	90.8	14.8	11.1	50.6	38.5	77

These figures indicate that clover hay usually carries more moisture than alfalfa or soybean hay, that it carries the lowest total and digestible protein, and that it carries the highest net energy value. If these figures are correct, clover hay should be equal to alfalfa hay or soybean hay for milk production except in rations in which protein is the limiting factor, unless there should be some factor not shown by chemical analysis.

Clover has usually been harvested when more nearly mature than has alfalfa, and this more mature condition accounts, in large measure, for its lower protein content. There is now a stronger tendency to harvest hays at an earlier stage of development. Willard (27) gives the following percentages of protein in alfalfa and clover hays cut at the same stage of development: alfalfa, 16.7 per cent; clover, 16.6 per cent. The protein content is, thus, not greatly different if the crops are harvested at the same stage and cured equally well.

Fraser (9), at the Illinois Station, fed good cows liberally and almost exclusively on alfalfa hay and corn silage. They averaged 7,470 pounds of milk and 262 pounds of fat. This test covered a period of 6 years.

At the California Station, Woll (28) fed alfalfa hay alone for 3 years. During their first lactations, six heifers produced an average of 5,743 pounds of milk and 204 pounds of fat. During the second year, three of them produced an average of 6,372 pounds of milk and 285 pounds of fat. Six heifers on alfalfa hay, corn silage, and grain produced during their first lactation periods 7,359 pounds of milk and 297 pounds of fat. Three of them during their second year produced 7,420 pounds of milk and 351 pounds of fat.

Hadley (11, 12) of the Nevada Station fed alfalfa as the sole ration to dairy cows in a long-time test. The cows lost weight from year to year, while those receiving some grain with alfalfa gained in weight. There was a tendency toward sterility among the cows fed alfalfa alone, but the difference was

small. This work was continued for 8 years, 1926 to 1934. The cows on alfalfa hay alone averaged 8,090 pounds of milk and 283 pounds of fat. The cows fed grain with the hay averaged 9,498 pounds of milk and 331 pounds of fat. In the 54 cow-years on hay alone, no serious effects on health, other than a tendency toward sterility, were noted. Blood phosphorus was below normal on alfalfa alone. The conclusion from this work was that feeding alfalfa hay alone was not profitable.

Jones et al. (19, 20) of the Oregon Station reported that in seven lactations, cows consumed an average of 9,031 pounds of alfalfa hay, 125 pounds of pea-and-oat hay, and 189 pounds of grain, and produced 4,464 pounds of milk (4 per cent fat) on a mature 305-day basis. Other cows receiving hay and grain produced 8,416 pounds of milk. Those on the hay ration produced 46.7 per cent less.

Graves et al. (10), Bureau of Dairy Industry, fed cows alfalfa without grain and secured a production of 11,375 to 13,656 pounds of milk and 402 to 478 pounds of fat. These were cows of large capacity and were milked three times daily. They were cows which on good rations produced 17,851 to 18,009 pounds of milk and 619 to 620 pounds of fat.

Huffman (17, 18) of Michigan found that alfalfa hay alone did not support high production and body weight.

Bechdel (3) compared high-quality alfalfa and clover hays for milk production. The cows receiving the clover hay produced 6.5 per cent less milk than those receiving the alfalfa hay, a difference somewhat in accord with the difference in protein content.

Hayden (13) of the Ohio Agricultural Experiment Station concluded from three short-time tests that alfalfa hay was not greatly superior to clover hay of equal quality for milk production and that alfalfa showed a greater tendency to maintain liveweight.

At the Kansas Station (26) Otis found soybean hay 98 per cent as valuable for cows as alfalfa hay.

Caldwell at the Ohio Station (7), in comparing alfalfa hay and soybean hay for milk production, found them about equal, but the cows made greater liveweight gains on the alfalfa ration, in a short test.

At the Pennsylvania Station, Bechdel and Williams (4) fed alfalfa and soybean hays to two groups of six cows each. The cows consuming soybean hay produced 3.9 per cent less milk than those consuming the alfalfa. In a second test, the cows receiving the soybean hay produced 3.3 per cent less milk than those receiving the alfalfa hay. Bechdel and Williams concluded that soybean hay was slightly inferior to alfalfa hay for milk production.

Moore and Cowsert (21) in a test at the Mississippi Station found that cows fed alfalfa or soybean hay produced about the same amount of milk, but slightly more fat, with the soybean hay. Those receiving the soybean hay lost more weight.

Olson (25), at the South Dakota Station, found soybean hay 6 per cent more valuable than alfalfa hay for milk production and 7.8 per cent more valuable for butterfat production.

Henderson (16), of the West Virginia Station, reported the results of four trials in which the reversal method was used. In the first two tests, the results were slightly in favor of soybean hay over alfalfa hay. In the third test, the advantage was slightly with the alfalfa hay, but the alfalfa was of better quality. The cows refused 3 per cent of the alfalfa and 23 per cent of

the soybean hay. In the fourth trial, about equal results were obtained. Henderson concluded that the two hays were about equal for milk production when they were of equal quality.

Morrison and associates (22, 23, 24) at the Wisconsin Station reported comparisons of alfalfa and soybean hays in which all the alfalfa was consumed and 17 to 19.2 per cent of the soybean hay was refused. Short reversal periods were used. The cows on the alfalfa ration produced slightly more milk per cow daily. The cows lost more weight on the soybean ration. These investigators estimated that the soybean hay was worth about 73 to 75 per cent as much per ton as the alfalfa hay. The difference was due largely to the large amount of soybean hay refused.

Hayden (14, 15) at the Ohio Agricultural Experiment Station showed that alfalfa hay, clover hay, and soybean hay fed as the entire roughage with ground shelled corn were capable of producing better than average growth in heifers.

The reports reviewed show that if they are cut at the proper stage and carefully cured, clover and soybean hays are close seconds to alfalfa hay and that much depends on the relative state of development when they are harvested and their quality is compared. The chief disadvantage of soybean hay seems to be the larger amount of coarse stems refused by the animals.

PLAN OF THIS EXPERIMENT

Three groups of three Holstein heifers each, from 7 to 11 months of age, were selected and fed continuously on the following rations: The heifers in group 1 (Nos. 316, 317, 318) were fed alfalfa hay and ground yellow corn. Those in group 2 (Nos. 334, 335, 337) were fed soybean hay and ground yellow corn. Those in group 3 (Nos. 340, 341, 342) were fed clover hay and ground yellow corn. (Cow 350 was later substituted for 340.) As much hay was fed as the animals would clean up well. Corn and hay were fed to the heifers in the proportion of one of corn to two of hay, and when the cows came into milk, the corn was fed somewhat in proportion to the amounts of milk produced. No pasture was allowed to heifers or cows.

Group 1, on alfalfa hay, was started June 1, 1925; group 2, on soybean hay, on June 1, 1926; and group 3, on clover hay, on November 16, 1926.

On December 18, 1929, cow 317 in the alfalfa group reacted to the tuberculin test and was removed. After calving, November 6, 1931, cow 335 from the soybean group did not clean properly, developed infection of the uterus, and was discarded as sterile. It is doubtful whether this condition was due to the ration. No substitution was made.

Heifer 340 (clover group) reacted to the tuberculin test February 1928 and was replaced by No. 350, 19 months of age.

When the heifers reached calving age, they were continued on the same rations through four lactations representing 4 years or more of production. Group 2 received some green soybeans in season when the hay supply was short. After four lactations, all groups were changed to a more normal ration consisting of alfalfa hay and a grain mixture containing four parts by weight of ground shelled corn, three parts of ground oats, one part of wheat bran, and one part of linseed oil meal. Some had pasture after the change. One or more lactations were obtained on this more normal ration.

Since these cows were started on this experiment before calving, they could not be divided according to actual production. However, they were more closely related than half sisters, as all except one were by the same sire (M 115) and from related dams. The one exception was by M 80 out of a daughter of M 115. Their dams were by M 80 and his sire (M 4), except the one by M 115 and one by M 60, an unrelated sire. The sire and grandsires of M 115 had seven, eight, and five daughters, respectively, each of which produced over 20,000 pounds of milk. His dam produced 20,876 pounds of milk and 802 pounds of fat in 305 days. M 115, however, proved to be a transmitter of medium to low production. Twelve of his daughters, on other rations, produced an average of 8,260.7 pounds of milk and 291.6 pounds of fat in 365 days after their first calves, 1,192 pounds of milk and 25 pounds of fat more than produced by the nine starting on the legume rations. Table 6 shows the relationship of these cows and their ages at starting. Since actual production records were lacking, this close relationship was the best that could be done to secure uniformity.

TABLE 6.—Relationship of cows and ages at starting

Herd number of cow	Sire	Sire of dam	Age at starting
	Alfalfa group		
316	M 115	M 4†	8 months
317	M 115	M 80	7 months
318	M 115	M 60	7 months
	Soybean group		
334	M 115	M 80	8.5 months
335	M 80	M 115	8.5 months
337	M 115	M 4†	8.5 months
	Clover group		
341	M 115	M 80	11.0 months
342	M 115	M 80	11.0 months
350*	M 115	M 80	19.0 months

*Substitute for 340.
†Sire of M 80.

The care was the same for all three lots of cows. They were kept in tie stalls and were turned out in a dry lot for a short time each day in winter. In summer they were out in the dry lot much of the time with water available. They were watered twice daily in winter and were allowed to drink as much as they would. They were milked and fed twice daily.

The weights of the animals were taken the last day of each month and the first day of the next. The average of these two weights was taken as the weight at the beginning of the month. In the summaries, the weights at birth, at the end of the first year, and at the end of the second year are given. For the later years, the average of the 12 monthly weights is given as being more representative than the weight at any one time, because of the variation due to gestation.

Daily weights of feeds consumed, complete records of milk produced, dates of breeding and calving, and other data were kept.

Most of the alfalfa and clover hay fed was bought on the market. A part of the soybean hay was bought, but most of it was produced on the Ohio Agricultural Experiment Station farm. There was considerable variation in the quality of all three hays. The alfalfa hay probably averaged grade No. 2. The soybean hay was, for the most part, of about equal quality. The quality of the clover hay was not quite so good. It proved more difficult to get clean red clover hay than the other hays. The red clover was usually cut at a later stage than alfalfa and contained small amounts of timothy, weeds, and stubble and some alsike.

The grain used in all groups came from the same lots. Unfortunately, it did not seem possible to make analyses of the feeds throughout the experiment; therefore, average analyses are used.

RESULTS

GROWTH

Table 7 gives the average weights of the cows, together with similar weights of half sisters fed various rations. The relative weights at 1 year of age are not significant, because the original heifers were not started on the experimental rations until 7 to 11 months of age. One substitute was 19 months old.

TABLE 7.—Average weights of animals at various ages

Age	Alfalfa group	Soybean group	Clover group	Average	Average of half sisters
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Birth	106	90	93	96	97
1 year	635	555	550	580	608
2 years	1,056	915	950	974	953
3 years	1,055	1,064	1,097	1,072	1,091
4 years	1,128	1,047	1,082	1,150	1,216
5 years	1,227*	1,095	1,151	1,159	1,303
6 years	1,225	1,167	1,230†	1,207	1,348
	(After change of rations)				
7 years	1,309	1,183	1,278	1,257	1,384
8 years	1,274	1,159	1,292	1,242	1,356
9 years	1,305	1,211*	1,290	1,269	1,390
10 years	1,310	1,205	1,267	1,260	.....

*One dropped out, two left.
†This figure is not the exact dividing line between the restricted and subsequent ration.

The half sisters on more varied rations were heavier than those on the alfalfa ration. Those on the alfalfa were very slightly heavier than those on clover, and those on soybeans were lighter than either of the other groups. A part of the lighter weight of the soybean cows was due to one cow (334) which was naturally smaller. Alfalfa seemed to develop the largest mature animals (14, 15); clover hay was second; soybean hay, third. The average difference for the last 3 years on the alfalfa and clover rations was but 6 pounds in favor of the alfalfa group. The average difference between the alfalfa and soybean groups for the last 3 years was about 100 pounds.

It is significant that the average weights of all three groups are 70 to 140 pounds lighter at maturity than the average of paternal half sisters which were on rations containing various grains and roughages. All grew at about

the same rate (fig. 1) until 2 years of age; but later, with reproduction and milk production, the weights of the cows on the test rations remained below those of the cows normally fed. Probably this break was caused by low feed consumption, but it may have been due to some deficient factor or factors, possibly, to a lack of a sufficient variety of proteins. In all groups, the cows appeared to be healthy, and they kept in fair to good condition. Their condition can be seen in figures 2 to 14.

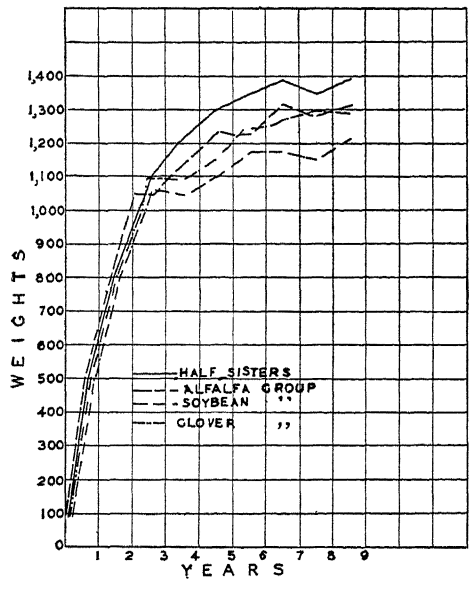

Fig. 1.—Growth as indicated by weight

REPRODUCTION

Reproduction difficulties, such as failure to come into oestrum properly, ovary trouble, retained placenta, and abortion, did not seem to occur more frequently among these cows than among other cows kept in the same barn. One abortion occurred in the alfalfa group, and another calf which came at full time and was well developed was dead. Cow 318 had some ovary trouble before the third and fourth conceptions. Her third calf was large; she labored for 4 hours; and the calf was dead when obtained. One calf in the clover group which came at full time and apparently was well developed was found dead in the yard. It was believed to have been born alive. Cow 335 in the soybean group developed an infection of the uterus after her third calf and became sterile. It is very doubtful whether the ration had anything to do with this condition. Cow 337 (soybean group) retained the placenta after her fourth calf and also at her fifth calving, at the close of the test, and was off feed at this calving. The calf was a little weak at birth and a little ahead of time. The sixth calving was normal, and the seventh calf, 2 years after the change to a more normal ration, was aborted, a condition which indicates a possible natural weakness. A considerable amount of such troubles as described was present in the herd at the time.

Unfortunately, some difficulty with sterile and uncertain bulls was encountered. One young bull used at the beginning of the experiment proved to be entirely sterile. A second bull became sterile through an infection, and a third, bought, was not very sure for a time after being moved to the Station. These difficulties caused some lactations of undue length. The average differences in length of lactations between groups, however, were less than 20 days.

In calculating the services per conception, shown in table 8, services by bulls which proved to be sterile at the time, as shown by service to other cows, were omitted, but where there was any doubt, services were not omitted.

For 12 conceptions on the alfalfa ration, 1.25 services were required per conception; for 13 conceptions in the soybean group, 1.38 services were required; and for 15 conceptions in the clover group, 1.73 services were required. The number was a little higher in the clover than in the other groups, but there was some question about one sire used in this group. None of these averages would be considered high for a herd average. The type of ration does not seem to have affected the conceiving ability to a significant degree.

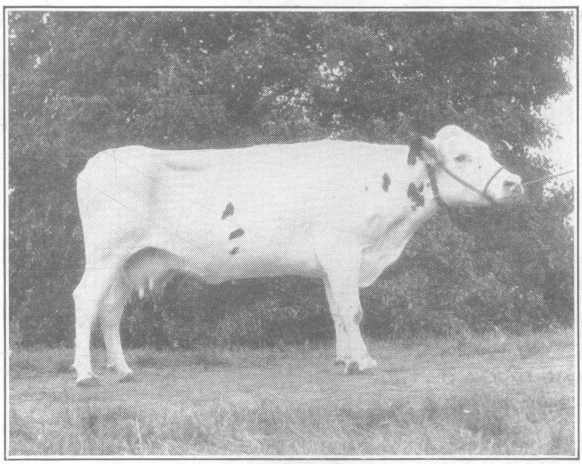

Fig. 2.—Cow 316, on the alfalfa ration 6 years, after milking for 7 months

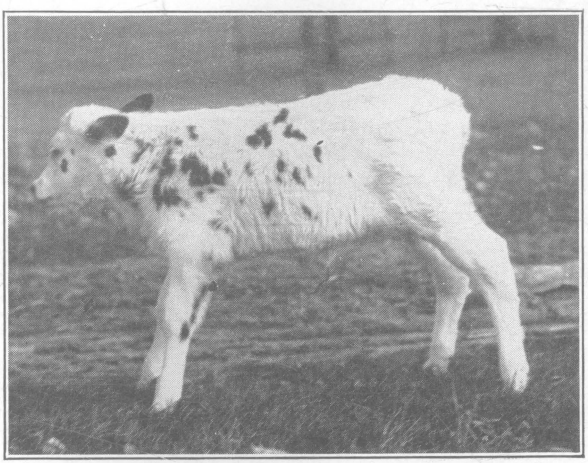

Fig. 3.—The third calf of cow 316; weight at birth, 90 pounds

TABLE 8.—Number of services per conception

Conception	Alfalfa group			Soybean group			Clover group		
	Cow 316	Cow 317	Cow 318	Cow 334	Cow 335	Cow 337	Cow 350	Cow 341	Cow 342
First	1	1	1	1	1	1	3*	1	3*
Second	1	1	1	1	1	2	2	3*	1
Third	1	.....	1	2	1	1	1	2	1
Fourth	1	.....	4	1	.....	1	2	1	1
Fifth	1	.....	1	1	.....	4	1	3	1
Averages	1	1	1.6	1.2	1	1.8	1.8	2.0	1.4
Group average	.....	1.25	.....	.....	1.38	.....	.....	1.73	.....
After change to a more normal ration									
Sixth	1	.....	1	1	.....	2	5	1	1
Seventh	4	.....	3	1	.....	1	.....	.....	1

Average of all groups after the change, 1.83

*There was some question about the sire used in these cases.

DEVELOPMENT OF CALVES

The average birth weights of the calves which the cows carried while on the restricted rations were as shown in table 9. These are arranged without regard to sires.

TABLE 9.—Average weights of calves at birth

	Males		Females	
	Number	*Pounds*	*Number*	*Pounds*
From the alfalfa group	2	96.6	7	88.6
From the soybean group	5	101.6	8	85.1
From the clover group	8	110.6	6	94.7

The calves from the clover group averaged, males, 9 pounds, and females, 6 pounds, heavier than those from either of the other groups. A part of this difference was due to the calves from one cow (341), all of which were large. If the calf weights are arranged according to sires and compared with those of 43 other calves from half sisters, those from the clover group still remain greater, as shown in table 10.

TABLE 10.—The average weights of calves at birth (by sires)

Sires	Alfalfa group		Soybean group		Clover group		43 other calves
	Number	*Pounds*	*Number*	*Pounds*	*Number*	*Pounds*	*Pounds*
M 80	5	87	2	82.5	1	80	85.5
M 263	1	81	.....	.....	3	100.7	91.8
M 280	1	90	3	87.3	2	100.5	.....
M 281	3	97	8	95.2	7	108.7	99.2
Average	.....	88.7	.....	88.3	.....	97.5	92.1
Weighted average	.....	89.7	.....	91.4	.....	103.4	.....

The numbers of calves and dams in these comparisons are too small to make the results really significant.

When the average weights of the female calves at birth are compared with the birth weights of their dams, they are lower in the alfalfa and soybean and higher in the clover group, as shown in table 11.

TABLE 11.—Average birth weights of the dams and their daughters

	Alfalfa group	Soybean group	Clover group
	Pounds	*Pounds*	*Pounds*
The dams	106.0	90.0	93.0
Daughters	88.6	85.1	94.7

FEED CONSUMPTION

At no time did the cows in either group consume large amounts of hay. The consumption and production fell far short of results obtained by some other investigators feeding alfalfa hay only. The low consumption and production may have been due largely to three factors, the moderate productive ability of the cows on test; the requirement that they clean up the hay reasonably well; and the effect of the restricted rations on the animals. They were not satisfied and would steal a mouthful of other feeds when an opportunity occurred. The average daily consumption of hay and grain, including the time when they were dry, by the individuals of each group was as shown in table 12.

TABLE 12.—Average daily consumption of hay and grain

	Hay	Grain
	Pounds	*Pounds*
Alfalfa group	16.19	9.61
Soybean group	16.06	10.37
Clover group	18.41	10.55

The cows may have consumed larger quantities of clover hay because the clover was not at all times clean medium red clover. At times it contained a considerable amount of alsike and at times a small amount of other materials. This variety may have influenced palatability. Clean, pure medium red clover hay was difficult to get.

MILK PRODUCTION (FIVE COMPARISONS)

In this study of production, five comparisons are made:

1, the production and consumption of all cows which were in the experiment one or more lactations
2, the production and consumption of those cows only which went through 4 years or more on the restricted rations
3, the consumption and production during 305 days after each calving

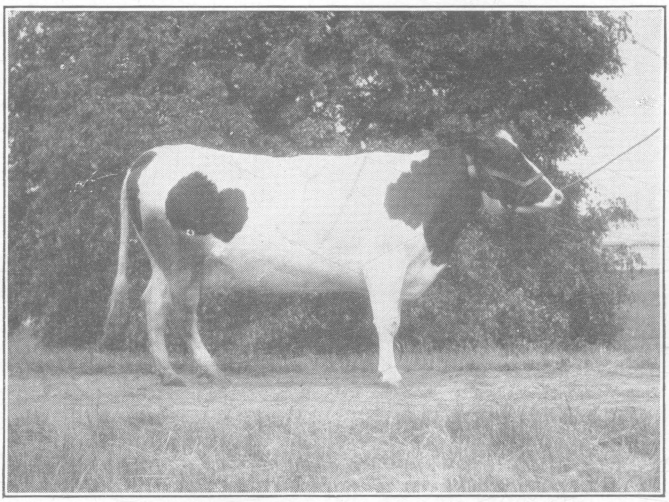

Fig. 4.—Cow 318 on the alfalfa ration as she appeared 2 months before dropping her fourth calf and after having been on this ration for 6 years

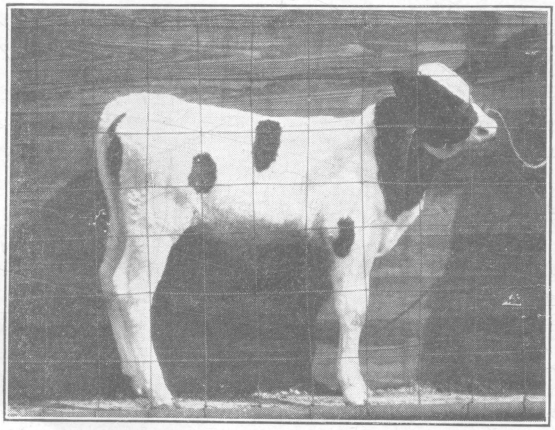

Fig. 5.—The first calf of cow 318. It weighed 90 pounds at birth and 193 pounds at 2 months of age, when this picture was taken.

4, the production during the last 2 years while on the restricted rations compared with that after the change to a better ration
5, the production with and without bone meal in the ration

COMPARISON 1, ALL COWS WITH ONE OR MORE LACTATIONS

The average consecutive 365-day consumption and production per cow by the three groups are shown in table 13. This table includes the production and consumption of all the cows which were in the experiment for two or more lactations (cow 317, two lactations).

TABLE 13.—The average time, annual production, and feeds consumed

Group	Time	Milk	Fat	Milk (F.C.M.)*	Grain	Hay
	Year	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Alfalfa	4.43	6,183	222.96	5,817.6	3,438	5,756
Soybean	4.73	6,733	243.59	6,347.0	4,094	5,768
Clover	4.85	6,560	246.01	6,314.2	3,885	6,466

*The milk was corrected to a 4 per cent fat basis by the Gaines formula

The alfalfa group was lowest in milk and fat production and in feed consumption. The soybean group was highest in grain consumption and in milk production, and the clover group was the highest in fat production and in hay consumption. The highest 365-day record was 10,978 pounds of milk and 369 pounds of fat by cow 335 on the soybean ration. She was the one by sire M 80 and proved to be the best producer in the three groups. She dropped out of the experiment at the end of her third lactation. Her consecutive 365-day production during the three lactations was 7,933 pounds of milk, on the 4 per cent

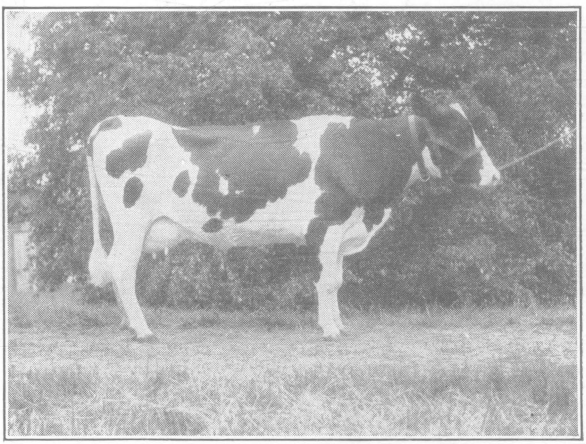

Fig. 6.—Cow 334 on the soybean ration, 2 months after calving and after she had been on the ration for 5 years

basis, and 303 pounds of fat. Cow 341, highest in the clover group, produced 10,092 pounds of milk and 337 pounds of fat. The highest record in the alfalfa group was 8,090 pounds of milk and 310 pounds of fat by cow 316 in her third lactation.

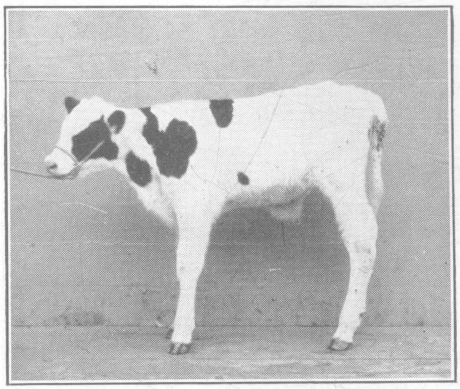

Fig. 7.—The calf dropped by cow 334, 1 month after the ration was changed; weight, 97 pounds at birth

COMPARISON 2, ONLY THE COWS THAT WENT THROUGH THE EXPERIMENT

Table 14 contains production data from only those cows which went through the 4 or more years on the restricted rations and one or two lactations after the change of rations. In this table the average annual production of milk and fat and the consumption of feeds are presented. The records are calculated on a consecutive 365-day basis.

TABLE 14.—The average time, milk and fat produced, and feeds consumed by all cows going through the experiment

Cow	Time Years	Milk Pounds	Fat Pounds	Milk (F.C.M.) Pounds	Grain Pounds	Hay Pounds
Alfalfa group						
316	6.1	6,658	224.43	6,329.6	3,704	5,982
318	5.7	5,713	196.11	5,226.8	3,280	5,833
Average	5.9	6,185	210.27	5,778.2	3,492	5,907
Soybean group						
334	4.98	5,780	206.35	5,407.2	3,286	5,708
337	5.10	6,065	221.03	5,741.4	4,276	5,827
Average	5.04	5,923	213.69	5,574.3	3,781	5,767
Clover group						
341	4.87	7,092	241.00	6,451.8	4,176	6,594
342	5.15	6,594	264.50	6,605.1	3,859	6,419
350	4.52	5,994	232.55	5,885.8	3,619	6,384
Average	4.85	6,560	246.01	6,314.2	3,885	6,466

The data in table 14 show that the highest average production of milk and fat and the highest consumption of feeds were in the clover group. The alfalfa group stood second, and the soybean group, third. Because the clover group stands at the top does not necessarily indicate that the clover was superior, for the cows in the clover group may have been naturally better producers. There is some indication that they were, for the clover group made the greatest increase in production when the cows were given the better ration, which included alfalfa hay. If they had been fed alfalfa during the test, they might have done even better.

The condition of some of the alfalfa cows at slaughter gave some indication that the clover cows may have remained in better health.

The production in all groups was low, but it must be remembered that the cows were on these restricted rations without pasture or green feed for 6 to 8 years, except for some green soybeans fed to the soybean group when the hay was short. Also, the records were calculated on the consecutive 365-day basis, regardless of the number of times the cows calved, and over long lactations due to sterile sires. The average production of 4 per cent milk for 365 days after each calving by the alfalfa, soybean, and clover groups, respectively, was 7,121, 6,752, and 7,181 pounds.

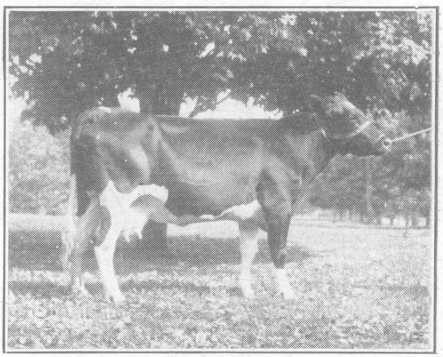

Fig. 8.—Cow 335 as she appeared at the end of her third lactation after having been on the soybean ration from 8½ months of age

The numbers of cows are too small to permit definite conclusions, especially with the variations shown. The lowest producer in the clover group was exceeded by one cow in each of the other groups. The lack of numbers is made up to some extent by the length of the experiment. The two cows on the alfalfa had a total of 11.8 cow years; those on the soybean ration, 10.08 cow years; and the three on clover ration, 14.54 cow years of production.

The total digestible nutrients, the total protein, and the digestible protein consumed are shown in table 15, also the amount of these nutrients used per 100 pounds of milk (F. C. M.) produced. Maintenance was not deducted. Average percentages were used in calculating nutrients.

TABLE 15.—Nutrients consumed annually and per 100 pounds of milk (F. C. M.) produced (including maintenance)

Group	Total digestible nutrients		Total protein		Digestible protein	
	Fed	Per 100 pounds of milk	Fed	Per 100 pounds of milk	Fed	Per 100 pounds of milk
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Alfalfa	5,785.8	100.1	1,196.5	20.7	874.0	15.1
Soybean	5,965.6	107.0	1,208.9	21.7	908.5	16.3
Clover	6,487.1	102.7	1,127.5	17.9	728.4	11.5

The alfalfa group required the least total digestible nutrients per 100 pounds of milk and the soybean group the most. The clover group consumed the lowest amount of both total and digestible protein per 100 pounds of milk. This result indicates that the clover protein was at least as effective in milk production as that from the alfalfa or soybean hay, unless milk production was limited by the energy supply rather than by the protein supplied. Later figures will show that more nutrients were consumed than required for the milk produced.

COMPARISON 3, THREE HUNDRED AND FIVE DAYS AFTER EACH CALVING

In this comparison, maintenance requirements, calculated by the use of Morrison standards (22) on the average monthly weights of the cows during the 305-day periods, were deducted. The production of milk (F. C. M.), the digestible nutrients consumed, and the total and digestible protein, also Morrison factors, are shown in table 16.

TABLE 16.—Pounds of milk (F. C. M.) produced and nutrients consumed in 10 months (305 days) after calving

Group	Milk	Digestible nutrients	Minimum for maintenance	Nutrients per 100 pounds of milk	Recommended maintenance	Nutrients per 100 pounds of milk	Morrison standards, 4 per cent milk	
							Minimum	Recommended
Total digestible nutrients								
Alfalfa	6,623.0	5,154.2	2,756.9	41.64	2,438.8	36.82	30.70	32.40
Soybean	6,323.4	5,382.3	3,110.1	49.17	2,808.1	44.39	30.70	32.40
Clover	6,618.5	5,588.3	3,157.0	47.93	2,832.8	43.01	30.70	32.40
Total protein								
Alfalfa	.....	1,046.49	.....	15.80	.....	.....	.....	.....
Soybean	.....	1,073.66	.....	16.97	.....	.....	.....	.....
Clover	.....	949.74	.....	14.34	.....	.....	.....	.....
Digestible protein								
Alfalfa	.....	765.08	559.22	8.44	542.28	8.18	4.10	4.90
Soybean	.....	807.42	612.08	9.68	595.91	9.42	4.10	4.90
Clover	.....	622.41	414.40	6.29	396.92	5.95	4.10	4.90

It will be noted that more total digestible nutrients and more digestible protein were consumed per unit of milk than called for by either the minimum or recommended standard. The alfalfa group used the least total digestible nutrients and the soybean group the most, per 100 pounds of milk. The clover group used the least total and digestible protein. This result does not indicate any inferiority of clover protein for milk production. Since the hays were not regularly analyzed, it is possible that the clover hay carried slightly more protein than calculated.

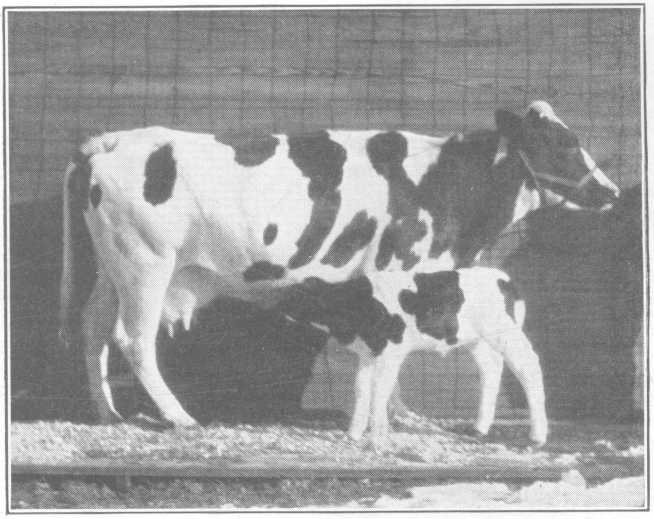

Fig. 9.—Cow 337 after having been on the soybean ration 3 years and 6 months, with her second calf, 1 day old. The calf weighed 100 pounds at birth.

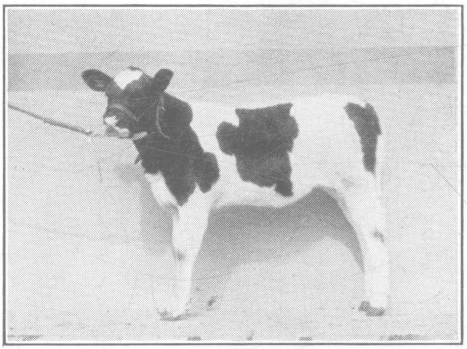

Fig. 10.—The second calf of cow 337, at 2 months of age; weight, 170 pounds

COMPARISON 4, THE LAST TWO YEARS ON THE LEGUME RATION AND THE YEAR FOLLOWING

In this comparison, the production in the last two lactations (consecutive 365-day basis) on the restricted rations is compared with that after the change to alfalfa hay and a better grain mixture. The results are shown in table 17. This method eliminates the heifer lactations and makes the ages more comparable. It is, therefore, a more correct measure of the difference due to the change of rations. The grain mixture in the new ration consisted of four parts

by weight of corn, three parts of oats, and one part each of wheat bran and linseed oil meal. Most of the cows received some other roughage with the alfalfa hay, and some pasture.

TABLE 17.—Average production in two lactations before the change of ration and in one or two after the change

Group	Milk			Fat			Milk (F.C.M.)		
	Before	After	Difference	Before	After	Difference	Before	After	Difference
Alfalfa	5,855	6,939	1,084	209.02	250.05	41.03	5,477.3	6,526.3	1,049.0
Soybean	6,354	6,938	584	224.50	241.75	17.25	5,909.1	6,401.4	492.3
Clover	7,414	8,650	1,236	269.77	317.31	47.54	7,012.1	8,219.6	1,207.5

The cows from the alfalfa group, which remained on alfalfa hay but had the change in grain and other feeds, gained 1,048 pounds of milk and 41 pounds of fat; those from the soybean and corn ration gained 584 pounds of milk and 17.25 pounds of fat; and those from the clover and corn ration gained 1,236 pounds of milk and 47.5 pounds of fat, per year.

The feeds and nutrients consumed after the change cannot be computed accurately, because most of the cows had some pasture. It is of interest, however, that the group continued on the alfalfa hay ate less hay than previously, while the cows previously on the soybean and clover hays ate much more of the alfalfa, an indication that the cows tired of the one kind of hay.

COMPARISON 5, WITH BONE MEAL ADDED TO THE RATION

Since these test rations contained neither high-protein grains nor mineral supplements, they were low in phosphorus (5). Therefore, some of the cows in each group were fed bone meal at the rate of 2 ounces daily for a part of the time to determine the effect of bone meal on production. Production records before and after feeding the meal were compared with the records obtained while it was fed. Also, the gains in production (due to age) by the cows which were not receiving the bone meal, over like periods, were compared with the gains of those receiving the bone meal. After allowances were made, as far as possible, for these variables, it appears that the bone meal increased the production about 600 pounds of milk and 20 pounds of fat per year.

Unfortunately, blood analyses were not made in the laboratory until near the close of this experiment, but when they were, seven samples from four cows fed bone meal contained 6.04 milligrams of phosphorus per 100 cubic centimeters of blood plasma, and a like number of samples from the same cows after the bone meal was discontinued contained 5.38 milligrams. The latter is within the normal range. The calcium content of the blood did not seem to be affected, and there seemed to be no significant difference between groups in the blood phosphorus or calcium while the cows were on the three hays without the bone meal. The lack of phosphorus in the rations of cows receiving no bone meal over a period of 6 years did not seem to have any serious effect on their health.

Cow 341, on the clover ration, received no bone meal and produced the largest calves in the three groups.

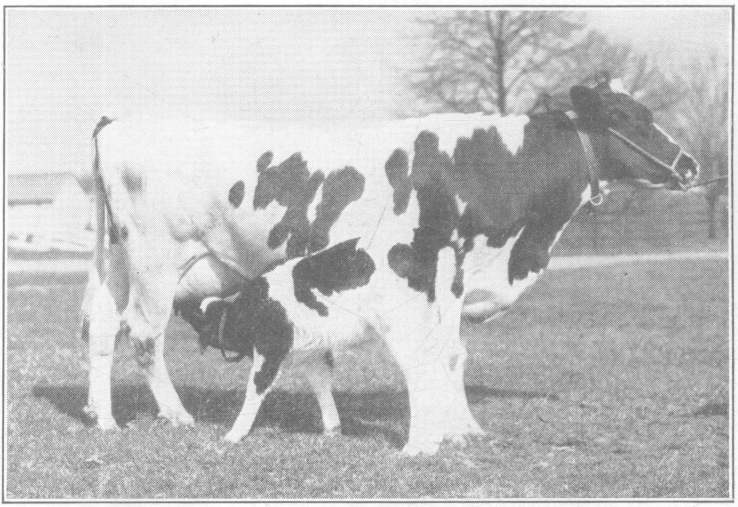

Fig. 11.—Cow 341 on the clover ration and her third calf, 13 days old; weight at birth, 125 pounds

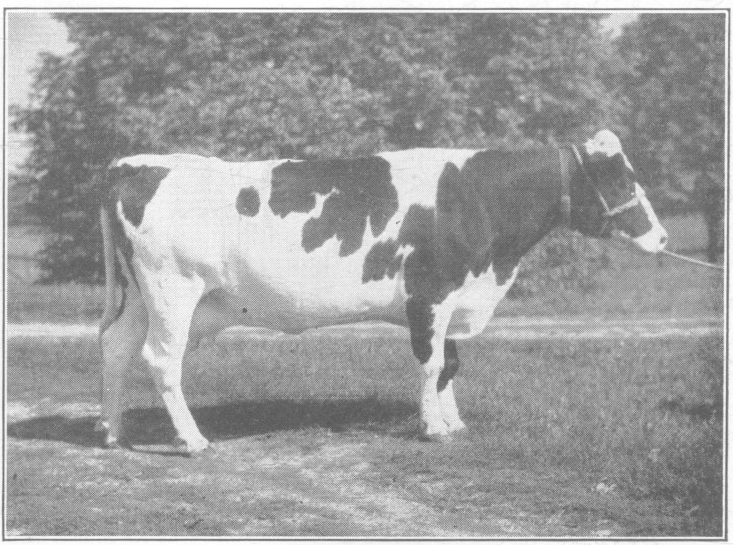

Fig. 12.—Cow 342 on the clover ration 6 years and 7 months, about 70 days before calving

HEALTH

Breeding difficulties were discussed in connection with reproduction.

Cases of mastitis occurred in all groups, also in other members of the herd. One cow in the soybean group had two attacks of "mad itch" about the head and neck. One case occurred while she was on the soybean hay, and the

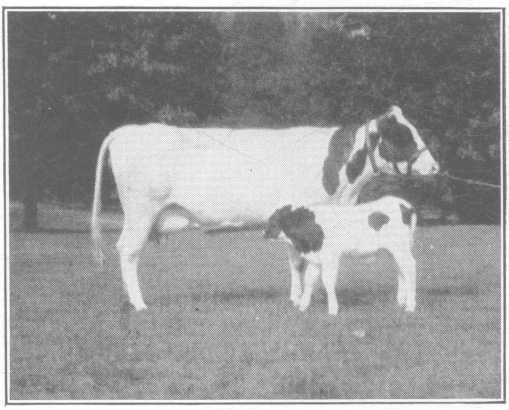

Fig. 13.—Cow 350 on the clover ration and her second calf; weight of calf at birth, 107 pounds

second, a year after the cow was changed to alfalfa and mixed grains. She soon recovered. This same trouble had occurred previously in two or three other cows in the herd. Retained placenta occurred once in the alfalfa group and twice in each of the other groups.

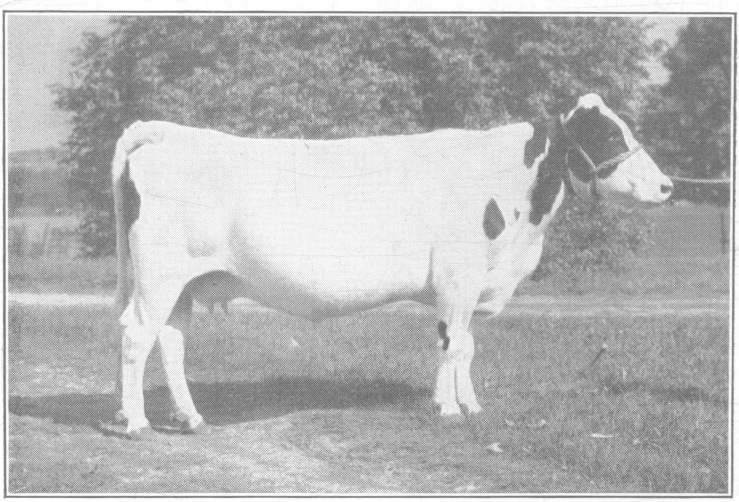

Fig. 14.—Cow 350 as she appeared 26 days before calving after being on the clover ration 5 years and 7 months

Outward appearance indicated that all the other cows were healthy, but cow 334, on soybeans, was off feed and appeared to be suffering from indigestion for a time at the close of the experiment. She recovered but did not pick up well after changed to the alfalfa and mixed grain ration. When this cow was slaughtered, her liver was greatly enlarged, and the pericardium was filled with pus.

Cows 316, 317, and 318, on alfalfa, had badly abscessed livers when slaughtered. One case was reported as probably due to a foreign body, but no definite foreign body was reported. This cow was slaughtered after being on the ration for 3½ years. The other two were slaughtered 22 months, and about 4 years, after they were removed from the restricted ration but continued on alfalfa hay.

Unfortunately, there is no definite post-mortem report available on two of the soybean cows and the three clover cows. They had been off these rations some time before slaughtered.

SUMMARY AND CONCLUSIONS

Three groups of Holstein heifers were fed ground shelled corn with alfalfa, soybean, and clover hay, respectively, until they had gone through 4 years or more of milk production.

The growth of these heifers was normal until they came into milk. The live weights then lagged until at maturity they averaged 70 to 140 pounds below the average of half sisters kept on more varied rations.

The reproduction of the groups on the different kinds of hay was about equal to the normal for the herd.

Breeding and other difficulties while the cows were on these rations through four lactations did not seem to occur more often than among other cows kept in the same barn and on more normal rations.

The birth weights of the calves carried while the cows were on these restricted rations were somewhat lower than those of their dams in the alfalfa and soybean groups and slightly higher in the clover group. The average weight of those from the clover group was the highest, owing in part to the large calves from one cow in the clover group. This result supports the author's opinion, based on previous observation, that high-quality medium red clover hay is probably the best single roughage for cows in late pregnancy and for junior calves.

The consumption of feeds and production of milk by the cows going through the experiment were highest in the clover-corn group, but the difference was scarcely significant. In none of the groups was the consumption as high as was anticipated, owing, no doubt, to the restricted rations. Total digestible nutrients consumed per 100 pounds of milk (F. C. M.) during the entire time were: in the alfalfa group, 100.1 pounds; in the soybean group, 107.0 pounds; and in the clover group, 102.7 pounds, including maintenance. During the 10 months after each calving, the alfalfa group consumed the least feed and the clover group the most. The alfalfa group consumed, above maintenance, the least total digestible nutrients per 100 pounds of milk, and the soybean group the most. The clover group consumed the least protein per unit of milk. All groups consumed more nutrients per unit of milk than called for by even a liberal standard, a result that indicates poor utilization of nutrients on the restricted rations. The addition of bone meal to these rations appeared to increase milk production about 600 pounds per cow per year.

The livers of the three alfalfa cows and one soybean cow were reported in bad condition when these animals were slaughtered.

The results of this long-time test do not show a marked superiority of alfalfa hay over clover or soybean hays for milk production.

Clover protein seemed to be fully equal to alfalfa protein for milk production. If production was limited by the quality of the protein, the clover protein must have been the best.

No single kind of legume roughage should be fed exclusively over long periods of time.

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